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GUIDELINES FOR QUALITY ASSURANCE PROGRAMS FOR MOBILE SOURCE EMISSIONS MEASUREMENT SYSTEMS: PHASE III. LIGHT-DUTY DIESEL-POWERED VEHICLES - QUALITY ASSURANCE GUIDELINES

Olson Laboratories,
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Quality Assurance guidelines for Light Duty Diesel Powered Mobile Source Emissions Measurement Systems are presented with the concept of a total Quality Assurance System. The guidelines apply to Quality Assurance principles and techniques in the areas of procurement, standards and calibration, test quality control, data validation and corrective action. Model Quality Management Procedures are presented to describe the relationships and responsibilities of the various organizational elements in accomplishing the quality functions. This volume is a supplement to EPA-650/4-75-024-a, Guidelines for QA Programs for Mobile Source Emissions Measurement Systems, Phase I, Light Duty Gasoline-Powered Vehicles - QA Guidelines.

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GUIDELINES FOR QUALITY ASSURANCE PROGRAMS FOR MOBILE SOURCE EMISSIONS MEASUREMENT SYSTEMS:

PHASE III, LIGHT-DUTY DIESEL-POWERED VEHICLES - QUALITY ASSURANCE GUIDELINES

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June 1975

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EPA REVIEW NOTICE

This volume has been prepared by Olson Laboratories, Incorporated consistent with the Environmental Protection Agency Quality Assurance principles and concepts and with the Environmental Protection Agency Mobile Source Testing Practices at Ann Arbor, Michigan.

The guidelines and procedures are generally applicable to mobile source testing operations and are intended for use by those engaged in such measurement programs

It is requested that recipients and users of this document submit any comments and suggestions to the Project Officers.

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FOREWORD

All mobile source testing facilities have some elements (activities) of a quality assurance system built into their routine testing operations. These activities may not have been identified and/or integrated into a formal quality assurance program. It is the objective of these guidelines to provide guidance to both (1) facilities which desire to organize an integrated quality assurance program, and (2) facilities which may have already organized towards an integrated quality assurance program, but may desire to review their program as a result of the recommendations and suggestions included in these guidelines. The extent of implementation will depend upon the requirements of each individual test facility.

EXECUTIVE SUMMARY

Quality assurance guidelines for diesel-powered light duty mobile source emission measurements are quite similar to those previously reported for gasoline-powered vehicles EPA-650/4-75-024-a "Guidelines For Quality Assurance Programs For Mobile Source Emission Measurement Systems," Phase I, Light Duty Gasoline-Powered Vehicles, June 1975. The testing of a diesel vehicle requires certain modifications of the gasoline procedure for the determination of hydrocarbons. Basically, these differences involve elimination of the evaporative emission requirement, modification of the vehicle preconditioning and introduction of a heated flame ionization instrument to continuously monitor the hydrocarbon emissions. Quality requirements for these special modifications as well as the detailed test procedures used by the EPA, are presented in this document.

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Section 1

INTRODUCTION

The quality assurance staff of the EPA Quality Assurance and Environment Monitoring Laboratory, Research Triangle Park, North Carolina is responsible for the administration of a quality assurance program for air measurement systems, resulting from the implementation of the Clean Air Act. Standards for the emissions from light and heavy duty mobile sources have been promulgated, and procedures published for the measurement of their emissions and certification. Quality assurance guidelines, however, have not been previously specified for these mobile source emission measurement testing procedures. Such quality assurance programs are necessary to assure the integrity of the data resulting from these tests. This report presents guidelines for quality assurance programs for measurement systems used in mobile source testing according to the applicable requirements of the Federal Register for the 1975 model-year.

The guidelines for the quality assurance program for mobile source measurement systems are prepared in four phases.

- Phase I - For light duty gasoline-powered vehicles (cars and trucks)
- Phase II - For heavy duty diesel engines
- Phase III - For light duty diesel-powered vehicles (cars and trucks)
- Phase IV - For heavy duty gasoline engines

This document presents the guidelines for implementing a quality assurance program for the measurement of emission from light duty diesel vehicles (Phase III). Guidelines for the other phases are reported in separate documents.

1.1 OBJECTIVE AND SCOPE OF GUIDELINES

These guidelines provide information on general quality methods which may be used in emission testing. They were primarily designed for

use by management and supervisory personnel involved in the development or operation of quality programs. Upper management may use the guidelines to evaluate the quality programs which presently exist within their own laboratory or organization.

The measurement system for light duty diesel vehicles consist of the testing, calibration and analytical requirements; the operational and measurement procedures used; and the operational and measurement data obtained. The primary objective of this program was to analyze this system and apply the principles and techniques of modern quality assurance systems to the total testing process to assure the validity and reliability of the tests and the resulting test data.

Many of the guidelines and test procedures described in Phase I of this program are directly applicable to the light duty diesel vehicle emission measurement system. Consequently, the objective of this supplement is to provide additional information and procedures required specifically for light duty diesel emission tests.

1.2 FORMATION OF QUALITY ASSURANCE GUIDELINES

In order to identify those areas requiring special definition for Phase III, the report for Phase I was reviewed along with the available information concerning light duty diesel emission test procedures, to determine necessary revisions or modifications of the Phase I documents. Sections and paragraphs requiring revision are numbered identically to the original document to facilitate cross reference. Sections applicable in their entirety are noted as such.

The quality assurance guidelines for light duty vehicle emission measurement systems are contained in Sections 1 through 8, with all references appearing in Section 9. A summary of the contents of each section follows.

1.2.1 Section 1 Introduction

A description of the background, objective and organization of the guidelines.

1.2.2 Section 2 Organizing for Quality

A typical Quality Assurance Organization is presented. Quality functions are identified and the various key elements of a quality program are described.

1.2.3 Section 3 Measurement System Analysis

A description of the measurement system defining the equipment, test procedure specifications and tolerances, quality provisions and other requirements necessary for emission testing of light duty diesel vehicles.

1.2.4 Section 4 Guidelines for Performance Audits and Maintenance Procedures

General guidelines are presented for performance inspection and maintenance of instruments and equipment used in the measurement systems. Preventive maintenance programs are described for increasing the reliability and efficiency of the test equipment.

1.2.5 Section 5 Quality Assurance Guidelines for Documentation of the Measurement System

Guidelines for the development of a documentation system are presented with representative forms, a description of the manuals, data recording, and failure analyses used by a quality assurance program.

1.2.6 Section 6 Application of Statistical Quality Assurance Methods to the Emission Test System

Basic statistical techniques such as control charts, analysis of variance and data validation as applied to a quality system are described.

1.2.7 Section 7 Analysis of Variability in the Measurement of Emissions from Light Duty Vehicles

Sources of variability are identified and, where possible, quantified to show their effect on the data.

1.2.8 Section 8 Quality Assurance System (On Site) Survey

A procedure and survey form for conducting a quality assurance survey of a laboratory performing light duty emission testing is presented.

1.2.9 Appendices

Statistical techniques and nomenclatures appear in Appendix A-1. Appendix A-2 contains control chart multiplication factors. Appendices B-1 and B-2 include a glossary of terms and a list of abbreviations commonly used in the measurement system. Appendix C of Volume 1 contains general Quality Management Procedures (QMP) which define those functions identified as being necessary in a quality program.

Section 2

ORGANIZING FOR QUALITY

2.1 OPERATIONS MANAGEMENT

2.1.1 Quality Assurance Management

2.1.2 Emission Test Facility Management

Administrative procedures and Quality Assurance functions are identical with those of EPA-650/4-75-024-a "Guidelines For Quality Assurance Prgrams For Mobile Source Emission Measurement Systems," Phase I, Light Duty Gasoline-Powered Vehicles, June 1975.

Section 3

MEASUREMENT SYSTEM ANALYSIS

3.1 APPLICABLE FEDERAL REGISTER PROCEDURES

The measurement system for light duty diesel emission measurements are defined in the Federal Register, Volume 38, No. 151, dated August 7, 1973 and Volume 39, No. 205, dated October 22, 1974. The applicable paragraphs of the Federal Register are as follows:

Light Duty Diesel Cars	Light Duty Diesel Trucks	Title
85.101	85.301	General Applicability
85.102	85.302	Definitions
85.103	85.303	Abbreviations
85.176-1	85.376-1	Emission Standards for 1976 Model-Year Vehicles
85.175-7	85.376-7	Mileage Accumulation and Emission Measurement
85.175-9	85.376-9	Test Procedures
85.175-10	85.376-10	Diesel Fuel Specifications
85.175-11	85.376-11	Vehicle Preconditioning
85.175-12	85.376-12	Dynamometer Driving Schedule
85.175-13	85.376-13	Dynamometer Procedure
85.175-14	85.376-14	Three-Speed Manual Transmission
85.175-15	85.376-15	Four-Speed and Five-Speed Manual Transmission
85.175-16	85.376-16	Automatic Transmissions
85.175-17	85.376-17	Engine Starting and Re-Starting
85.175-18	85.376-18	Sampling and Analytical System
85.175-19	85.376-19	Information to be recorded
85.175-20	85.376-20	Analytical System Calibration and Sample Handling
85.175-21	85.376-21	Dynamometer Test Run
85.175-22	85.376-22	Chart Reading
85.175-23	85.376-23	Calculations

3.2 ELEMENTS OF A MEASUREMENT SYSTEM FOR LIGHT DUTY VEHICLE EMISSION MEASUREMENT

A requirement of a total quality assurance program is to maintain control at all important stages of a process. In this measurement system, an analytical process, it is necessary to first identify its functional elements. In order to categorize these elements, the measurement system has been divided into two basic operations:

- o Vehicle Preparation
- o Exhaust Emission Measurement

These two operations are further separated into the tasks or elements requiring quality consideration in Figure 3-1.

Figure 3-1. ELEMENTS OF A MEASUREMENT SYSTEM FOR LIGHT DUTY DIESEL VEHICLE EMISSIONS

FEDERAL TEST PROCEDURE

FOR

LIGHT DUTY DIESEL VEHICLES

VEHICLE PREPARATION
AND
PRECONDITIONING

- o Receive vehicle
- o Vehicle inspection
- o Preparation
- o Preconditioning

EXHAUST EMISSION
MEASUREMENTS

- o Dyno warm-up
- o Start-up procedure
- o CVS sampling
- o Analytical measurements
- o Data reduction

3.2.1 Evaporative Emission Measurement

This procedure is not applicable to diesel vehicles.

3.2.2 Exhaust Emission Measurement

A summary matrix of the vehicle preparation and exhaust emission measurement for light duty vehicles has been presented in Tables 3-2 and 3-4 in the report for Phase I. The emission test for the diesel vehicle is identical to that for the gasoline vehicle, with the following exceptions;

Preconditioning - AMA route is not required. Only a single 7.5-mile FTP cycle is run with a 12-hour soak period. This procedure is detailed in Test Procedure No. 703-D (Volume II, Phase III).

Exhaust Analysis - Because of the low volatility of the unburned fuel in the exhaust, a heated sampling system and FID detector are required. The sample is analyzed and concentration integrated during the complete FTP cycle. Details of this procedure are given in Test Procedure No. 707-D (Volume II, Phase III).

Specifications for the above procedural changes are listed in Table 4-1. Applicable test procedures for the light duty diesel emission measurement system are listed in the Table of Contents for Volume II of this report.

Section 4

GUIDELINES FOR PERFORMANCE AUDITS AND MAINTENANCE PROCEDURES

The guidelines presented in this section are applicable to both measurement systems. A listing of additional specifications for light duty diesel testing are presented in the following supplement to Table 4-1.

Table 4-1. FEDERAL REGISTER SPECIFICATIONS
LIGHT DUTY DIESEL POWERED VEHICLES

Reference Paragraph	Procedure or Equipment Description	Specification or Tolerance
85.175-10 85.376-10	Diesel Fuel Specification	Type 1-D and Type 2-D Refer to referenced paragraph for complete specifications (a) (b).
85.175-9	Vehicle Preconditioning	Fuel Temperature 68-86°F Fill to "Tank Fuel Volume" (40 percent of nominal tank volume). Run single FTP cycle (7.5 miles) at ambient of 68-86°F Soak - Min. of 12 hours 68-86°F
85.175-18(d)	Exhaust gas continuous analytical system	1. Heated continuous sample line, heated filter and heated pump. 2. Heated Hydrocarbon Analyzer (HFID) o Response time 90 percent full scale, 1 sec. o Sample transport time, 4 seconds o Chart record, chart recorder and analog integrator with two read-outs or chart recorder and on-line digital computer for manual or electronic integration of analyzer output signal during the three operating phases of the test
85.175-20(b)	Hydrocarbon Sample Handling	Set point 300-390°F ±10°F 20 minute warm-up, minimum for electronics, stabilization point for heated components. Start integrator for HC at start and end of bag sampling. Recorder chart may be integrated manually for checking integrator or computer.

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Section 5

QUALITY ASSURANCE FOR DOCUMENTATION OF THE MEASUREMENT SYSTEM

Section 6

APPLICATION OF STATISTICAL QUALITY ASSURANCE METHODS TO THE EMISSION TEST SYSTEM

The above two sections are directly applicable to both measurement systems. The general guidelines described for documentation and statistical methods may be incorporated into a quality system for all mobile source emission testing. When establishing a quality plan for a particular mobile source testing facility, these two sections of the Phase I report should be consulted for guidance in such areas as control of procedural manuals, recording of results, processing and audit control of emission data, initiating control charts and the implementation of corrective action procedures.

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Section 7

ANALYSIS OF VARIABILITY IN THE MEASUREMENT OF EMISSIONS FROM LIGHT DUTY VEHICLES

Since a majority of the procedures and equipment utilized for analysis of gasoline vehicle emissions are also used for the determination of exhaust emissions from diesel vehicles, the sources of variability are quite similar for both measurement systems. Test variability has been discussed in depth in the previous report and additional information on test error analysis may be obtained from the following recently published papers:

1. H. Klingenberg, M. Fock, K.H. Lies and L. Pazsitka, "A Critical Study of the United States Exhaust Emission Certification Test-Error Analysis for the Test Procedure." Presented at the 67th annual meeting of the Air Pollution Control Association, Denver, Colorado; June 9-13, 1974.

2. M. Fock, K.H. Lies and L. Pazsitka, "Critical Study of the United States Exhaust Emission Certification Test-Error and Probability Analysis," presented at the Society of Automotive Engineers Meeting, Houston, Texas; June 3-5, 1975; Paper No. 750678.

7.1 VARIABLES ASSOCIATED WITH THE MEASUREMENT OF EVAPORATIVE EMISSIONS

Because of the low volatility of diesel fuel (IBP.330-390F), evaporative emissions are not a significant contributing factor in the emissions from diesel-powered vehicles. Consequently, portions of the light duty procedure associated with this measurement are not performed on diesel vehicles.

7.2 VARIABLES ASSOCIATED WITH THE MEASUREMENT OF EXHAUST EMISSIONS

The measurement of CO, CO_2 and NO_x for both measurement systems are identical and the associated sources and magnitude of test error are quite similar as illustrated by Figure 7-2 in the report for Phase I,

which compares test variability associated with different types of control systems (gasoline) and the diesel engine. This data also shows the value of using a lower range for measurement of CO, which is compatible with the lower concentrations of CO emitted by diesel engines as compared to gasoline-powered vehicles.

Hydrocarbons (HC) must be determined differently because of their tendency to condense and form aerosols at ambient temperatures.

The diluted diesel exhaust is sampled continuously at a point just prior to the heat exchanger of the constant volume sampler (CVS). As this is the primary difference between the two measurement systems, the following paragraphs will discuss variables associated with this measurement.

7.2.1 Analysis of Variables Associated with Measurement and Reduction of Data

The continuous hydrocarbon trace is integrated electronically or manually for each portion of the Federal Test Procedure (FTP). An average concentration is determined for each phase, and the data reduced using the same formulas as for light duty gasoline emissions including a measurement and correction for background hydrocarbons in the dilution air bag sample.

Errors in determining the average concentration of hydrocarbons will have a direct effect on the resultant mass value. In addition to the sources of variability discussed in 7.2.1.3 of the Phase I Report, the concentration of hydrocarbons will be affected by the accuracy of the integrator and the response time (limited to 4 seconds) of the heated flame ionization instrument, especially during the transient modes of the cycle. These two particular sources of variability require periodic verification by manual integration of the recorder trace and response time. The response time is determined by the injection of a tracer gas (propane) into the inlet of the CVS. The electronic integrator could also be checked using the propane injections technique, by correlation with a bag sample collected concurrently with the integrated continuous sample.

7.2.2 Variation Associated with the Equipment and Test Procedures Used in the Measurement System

The sample handling system for diesel exhaust measurement requires a heated sample line, filter and FID detector. The prescribed temperature is 300° to 390°F controlled within ±10°F of the set point. This hydrocarbon sampling system has two unique sources of variability, the temperatures of the sampling system and partial oxidation of the

hydrocarbons. These sources are interrelated and have been of great concern in heavy duty testing, but have received little attention in light duty testing. Although not mentioned in the Federal Test Procedure, some form of optimization of response should govern the selection of the temperature set point for the sampling system. This might be achieved, for example, by varying the operation of a diesel engine at a steady-state, equilibrium condition.

The diluted exhaust sample is taken at a point just prior to the inlet to the heat exchanger of the CVS. The function of this heat exchanger is to maintain a constant temperature at the CVS pump inlet. A temperature of between 110° to 115°F is usually selected. To stabilize the temperature of the mix, the heat exchanger must heat as well as cool the exhaust, raising a rather obvious question. What happens to the hydrocarbons during the cold portion (first 505 seconds) of the test when the vehicle exhaust system, the inlet system of the CVS, and the temperature of the exhaust air mix are all very close to ambient temperatures? At the beginning of the test the exhaust hydrocarbons may absorb on the surfaces and of course desorb from these same surfaces during the "hot" portions of the test. This situation would, of course, give an incorrect exhaust profile integration. The magnitude of this effect remains to be determined.

The temperature of the sampling system must be uniform over its entire length. Hot or cool spots can cause erroneous readings of the exhaust hydrocarbons, such as low readings due to condensation resulting from cool spots. A high concentration of oxygen is present in the sample because the sample is diluted with air. Hot spots in the sample lines can cause partial oxidation of the hydrocarbons. Oxygenated hydrocarbons have a lower response coefficient for FID detection and give an erroneously low reading. The severity of the oxidation process would depend on the intensity of the "hot" spots and the response coefficients of the FID detector. When setting up a sampling system, the sample temperatures should be determined at several points along the system to assure that temperature uniformity does exist.

7.3 MEASUREMENT OF VARIABILITY IN EMISSION MEASUREMENT SYSTEMS

Variability of the measurement system is defined as the inability to achieve identical test results from repeated tests on the same vehicle without change to hardware or vehicle adjustment specifications. Variability exists in test results to varying degrees dependent on the type of variability, test-to-test, cell-to-cell within a laboratory, or laboratory-to-laboratory. Several examples of actual correlation data are given in the Phase I Report. In addition, data from an

interlaboratory correlation of four diesel vehicles are given in Table 7-1. These emission values are given in metric units which may be converted to the familiar g/mile basis by multiplying by 1.609.

Table 7-1. AVERAGE 1975 LIGHT DUTY EMISSION AND FUEL ECONOMY RESULTS

Emission	Lab	Nissan Datsun	Mercedes 220D	Peugeot 504D	Opel Rekord
HC,g/km	EPA	0.14	0.18	2.07	0.24
	SwRI	0.22	0.15	1.22	0.24
CO,g/km	EPA	0.84	0.59	2.52	0.75
	SwRI	0.84	0.66	1.47	0.61
NO_x,g/km	EPA	0.85	1.02	0.68	0.80
	SwRI	0.95	0.75	0.62	0.82
Fuel economy km/l Carbon balance	EPA	11.9	11.9	9.8	10.1
	SwRI	10.6	12.1	11.3	11.1
Gravimetric	SwRI	10.2	11.1	10.0	10.2

Reference: K.J. Springer, R.C. Stahman "Emissions and Economy of Four Diesel Cars." Presented at the SAE Automotive Engineering Congress and Exposition, Detroit, Michigan; February 24-28, 1975. Paper No. 750332.

Many of the precautions and checks mentioned in this section are included in the Test Procedures (Volume II). Each test facility, depending upon its experience and judgment, should carefully review this section to determine if some or all of the additional precautions and checks should be introduced into their operational test procedures as routine or periodic checks.

Section 8

QUALITY ASSURANCE SYSTEM SURVEY
Refer to Phase I Report

Section 9

REFERENCES
Additional references for this document were included in the text

APPENDICES A, B, AND C
Refer to Phase I Report